Chemistry 340 Spring 2004
Handout on writing technical reports

This first set of guidelines on writing a Technical Report is adapted from Alan Sherman at the University of Maryland.

Overview

The *Technical Report (TR)* is a common written form by which engineers, computer scientists, or scientists in industry or government agencies communicate their findings. Some journals, such as Nature Biotechnology and Bioinformatics, have special sections for TRs. Agency reports (CDC for example) often appear in abstract services such as PubMed, but not all TRs are part of the primary literature.

Each TR has a focused topic that is developed logically along some clearly identified perspective. Not unlike a scientific paper, the major components of a TR are a descriptive title, author name and affiliation, date, informative abstract, list of keywords, body, acknowledgments, and list of references. Additional separate appendices, where appropriate, may also be included. The standard four-part outline for the body of a technical report consists of motivation, methods, results, and discussion.

Like a scientific paper, the TR should explain what you did, why you did it, what you discovered, and what is significant of your findings. The report should identify clearly what is novel about your work, and how it relates to prior knowledge. There should be a focused topic, and an attitude about this topic. The topic should be developed according to the attitude in a thorough, logical, and orderly fashion. Throughout, the author should be helpful to the reader.

TRs have no minimum or maximum length, as the length should be appropriate to what you need to communicate. Typical TRs are 5-10 pages in length, but it is not uncommon to find TRs of 20 pages or longer. Journals that accept TRs usually specify the length in words, typically 2000-3000. Regardless of length, it is usually an effective strategy to explain your project/research in successive ``layers.'' Very long TRs usually begin with a relatively short overview section for readers who wish an executive summary. Quality and conciseness, not quantity, will be rewarded.

Thesis

Every TR should have a topic, or *thesis*, and an attitude about the thesis, which helps to focus the topic and provides a framework to explore the topic. The introduction of the TR should clearly identify its thesis and an organizational plan for developing the thesis. It is useful to think of this in terms of questions and answers: communicate the research by raising and answering very focused questions.

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The Components

A technical report should include each of the following items:

1. **A logical, accurate, descriptive, and grammatically correct title**. Please note: the title ``CMSC 441 Course Project'' is not descriptive. Titles should be as short as possible, while still satisfying the foregoing criteria. Avoid cute titles that violate these criteria. Two-part titles can provide short and long forms (e.g. ``Statistical Techniques for Cryptanalysis: An Experimental Study using Real and Simulated English''). Avoid titles that exceed 17 words.

2. **Author name and affiliation, and date**. For example, your affiliation might be ``Department of Chemical Engineering, Dupont, Inc.'' You might also like to include the city and state of your affiliation, your email address, and a URL to your home page.

3. **An informative abstract of approximately 200 words**. Make sure that your abstract is informative---your abstract should serve as a substitute for your paper. Briefly summarize your main findings. Concretely summarize; do not introduce. Immediately get to the point in the first sentence. Do not cite any references in the abstract, and do not begin the abstract with the weak, hackneyed, and boring phrase ``This paper ...''. The abstract should be informative yet understandable to most researchers in your general field. The abstract should fit on one title page, including the title, author name and affiliation, date, and list of keywords.

4. **A list of appropriate keywords**. These keywords should identify the field of your report and its major topics. Choose keywords to be helpful to researchers in locating your work in document-retrieval systems, as these keywords will be used to classify and identify your paper. What words and phrases should someone use to find your report? Be specific, and use only standard phrases. Many journals use three levels of keywords: general terms (e.g. protein crystallography), subject descriptors (e.g. protein crystallization) recognizable to most researchers, and implicit terms--specific words or phrases that act as proper names (e.g. pI, isoelectric point) which might not be recognizable to all readers.

5. **Body of technical report**. Write a clear, informative, and thoughtful description and critique of what you did. Where appropriate, include carefully drawn graphs and diagrams. Be sure to motivate, present, and interpret your findings.

   Focus on the scientific content of the project--your questions and answers. Identify and explain interesting and important phenomena. Emphasize what is new about your project. In addition, briefly comment on the 'engineering' aspects of your work: what problems did you face, what decisions did you make, and what are the consequences of these decisions? Although it is crucial to explain your experimental procedures, be concise and do not bore your reader with lengthy descriptions of routine implementation concerns.

   Pay attention to important transitional sentences, especially the first and last sentences of the report. There are three standard ways to begin the introduction: startling statement, dramatic incident, and quotation. End a report with a powerful sentence that concisely summarizes the significance of the entire project.

6. **Acknowledgments.** Acknowledge any help you received, including any use of equipment or helpful discussions. Be specific.

7. **Complete and accurate list of references cited in the technical report**. There are three reasons for citing works: to give credit where credit is due, to be helpful to the reader to identify useful related work, and to identify the context and background of your work. TRs use a bibliographic style that you the author adopt from a major refereed journal (e.g. use the style for JACS).

   List and number references by alphabetical order of author name. When citing references in the body of the report, always explain why the reference is being cited. For example, do not cite previous work without critically explaining how it relates to your work. Mention the author name in the textual citation, followed by the corresponding reference number (e.g. ``In 1976, Diffie and Helman [14] proposed the concept of public-key cryptography.").

8. **Appendices for supplemental information and for information that is too detailed or voluminous to fit into body of the technical report**. For example, if your project involves any computer programming, you should include a nicely documented and formatted listing of all source code you wrote.

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Organization

Although you are free to organize a TR in any way you see fit, a standard outline is one that resembled that for scientific papers:

- motivation (intro)
- methods
- results
- discussion.

Separate logical organization from explicit numbered sectioning, and think in terms of hierarchies. The logical introduction might include one or more numbered sections, depending on what needs to be said. A short report might begin with one section: 1. Introduction. A longer report might begin with a more elaborate logical introduction consisting of four numbered sections: 1. Introduction 2. Overview 3. Background 4. Previous work. As the report evolves you may wish to modify the organization. In describing the purpose of your project, restrict yourself to scientific and engineering reasons. If you discuss philosophy, do so in the discussion section. Do not repeat sentences from the abstract verbatim. Bottom line: you should explain what it all means to you.

Experimental Work

Be sure to explain your procedures, to present your results, and to interpret your results. Summarize your findings in meaningful ways, visualizing important data (e.g. in graphs) whenever possible. Be sure to explain your procedures in sufficient detail so that other researchers can verify and replicate your findings.

Evaluation

TRs, like scientific papers, are evaluated on the basis of their scientific merit and effective presentation. Scientific merit includes correctness, significance, novelty, nontriviality, and completeness. Rewards come from thorough analysis, originality, and insightfulness.

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Common Mistakes to Avoid

Adhere carefully to the following guidelines:

1. In the introduction of your report, clearly identify a focused well-defined question. Answer this question in the rest of your report.

2. Analyze and interpret your data, and discuss the significance and limitations of your findings. Do not simply report your data.

3. Be sure that your technical report is complete in the sense that it has each of the following components: descriptive title, author name and affiliation, date, informative abstract, list of keywords, body, acknowledgments, and references.

4. In your abstract, specifically and concretely state your findings; do not vaguely describe what you set out to do. Your abstract should summarize, not introduce. Do not begin your abstract with the hackneyed phrase ``This paper."

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The following guidelines for writing technical reports are adapted from NASA.

Never assume that your job is finished when the experimental or analytical phase has been completed. It is also your responsibility as an engineer or scientist to show promptly that your results are worthwhile and that you have reason to believe the field will be advanced by your efforts. The only way to convey these thoughts is by writing a good report. The five major stages of report preparation follow.

1. Gathering the Data (or developing the theory)

Report preparation begins with planning the research program. An orderly investigation is a requisite for an orderly report. Report planning and program planning should be considered one and the same. To become a successful technical writer, you should develop the ability to foresee the general content of the report before the program begins. In most cases you should be able to prepare a preliminary report outline at the beginning of the program. Outlining should benefit both the report and the program, for obviously a well-prepared outline requires a carefully planned program.

During the course of the program keep the future report in mind. Maintain orderly records as the data are gathered. The little extra time required to record the results carefully can be of great value later. Report writing is difficult enough without having to recollect misplaced or unrecorded data. Write out your opinions as soon as the data are obtained. Comparing these opinions with those based on hindsight will often help you to interpret the data properly.

During the data-gathering stage consider how the data should be presented in the report and record the results in this manner. Any need for additional data will thus be revealed before the program is completed.

2. Analyzing and Sorting the Results

The second stage of report preparation, data analysis and sorting, is probably the most difficult because it requires considerable mental effort to decide what you want to tell your readers. The beginning of this stage overlaps the data-gathering stage, for data analysis should begin as the data are collected. But the bulk of data analysis must be done near completion of the program. At this time reexamine the pertinent data and review your earlier opinions with respect to subsequent results.

During this data review the program conclusions should be drawn. This is the most important step in report preparation because the conclusions are the reason for the report and the basis for report preparation: They dictate what to include in a report and how to organize it. Trying to organize and write a report without knowing the conclusions is like starting an automobile trip without knowing the destination. You will not know where you are going, and you will never know when you get far enough to stop. Therefore choose your report destination early by drawing and clearly defining the program

conclusions before you begin to organize and write the report. This is best done by first writing down all significant results in no particular order and then sorting them so that the results pertaining to a common factor are grouped together. Once the conclusions are drawn, list them in descending order of importance.

Selection of the data to be used in the report is another important part of this step. Choose only the data necessary to help your readers reach the conclusions you are drawing. Excessive data or data only loosely related to the conclusions will obscure them and confuse your readers. Of course, do not hide contradictory results. When definite contradictions exist, clearly alert your readers to this fact.

The next step in data analysis involves organizing the selected data into illustrations for the report. Sometimes the figures and tables prepared during the program can be used with only minor modifications. But usually these data-book illustrations contain extraneous information. And they seldom are arranged to emphasize the significance of the data and the corresponding results. For example, although data tabulated during a program are commonly arranged chronologically, that is not necessarily the best way to present the data to the reader.

New figures and tables usually must be prepared. Their organization should be carefully considered because illustrations are one of the best means of emphasizing and supporting conclusions.

After the illustrations have been prepared, write the significant points about each on an attached sheet of paper. What is the figure (table) supposed to show? How were the data obtained? Are there any qualifications to the figure (table)? This information will be useful when you begin writing the report.

Before beginning to outline your report you may find one additional step useful—writing a limiting sentence. This is a single sentence that states the subject, scope, and purpose of the report. It is an additional tool to help define the report's direction and limit its scope. As an example, the following limiting sentence could be written for this guide:

SUBJECT The Glenn Research Center guide “Technical Report Writing”
SCOPE covering the fundamentals of organizing, writing, and reviewing NASA technical reports,
PURPOSE was written to improve the writing skills of Glenn technical authors and the overall quality of their reports.

Preparing a limiting sentence is not simple. It takes additional time and effort. But it is a worthwhile exercise because it forces you to focus your attention on exactly what you expect the report to do.

3. Outlining the Report

Outlining is a necessary preliminary step to report writing. It involves the planning needed to prepare a clear report that is logically organized, concise, and easy to read. Without an outline most inexperienced authors write reports that are confusing and difficult to follow. The outlining stage is a natural progression from the analysis and sorting stage. In the sorting stage concentration is on what results should be presented in a report. In the outlining stage attention is directed to *how* these results should be presented.

Often the preliminary outline prepared at the beginning of the program can be used as a starting point for the report outline. But it should be revised and expanded to emphasize the conclusions drawn in the analysis and sorting stage. The revised outline should contain descriptive headings of each significant part of the report. This expanded outline should show the complete scope of the report, the relation of the various parts of the work discussed, the amount of space to be given each part, the order of treatment, the places for inclusion of illustrations, and the conclusions. Remember, the more detailed the outline is, the more useful it will be to you. Each heading, subheading, subsubheading, etc., should have as much detail as you will need to trigger your thoughts when you later write the corresponding sentences and paragraphs.

NASA reports typically contain a number of commonly used headings:

- Summary
- Introduction
- Symbols
- Theory
- Analysis
- Apparatus
- Test Specimens
- Test Procedure
- Sample Calculation
- Results and Discussion
- Summary of Results
- Conclusions
- Concluding Remarks
- Appendix
- References

All these headings need not be used in any single report. And headings may be combined. For example, Apparatus, Test Specimens, and Test Procedure can be combined into Experimental Methods.

These commonly used headings may be replaced with more descriptive headings, particularly in program summary reports, where details may be subordinated to broad objectives and generalizations. In these reports the more descriptive headings provide a

means of ready reference and aid clarity. Descriptive headings usually make a report more interesting to read. But you must exercise originality to make them brief but clear.

The final outline should show the exact form, wording, and value of the headings to be used in the report. The headings, although brief, must serve as a reliable guide to the included material. They should be consistent in grammatical structure and should not contain verbs. Headings are not an integral part of the text but are provided to assist the reader in finding information. Therefore the paragraph below a heading should begin with a topic sentence that does not depend on the heading for clarity.

The whole text of the report should be accounted for under the headings shown in your outline, except for short introductory or transition paragraphs included to make the presentation flow smoothly. Because a subject cannot be subdivided into less than two parts, an outline should have at least two subheadings under a main heading—or none. Exceptions to this rule include an occasional short remark or a single example put in to illustrate a method. In addition to headings the outline may also contain descriptive words and key phrases to serve as reminders.

Several methods can be used to arrange the subject matter that will be represented in an outline. One of the best ways to start is to write down all the points that you want to include without regard to their order. You can then more easily arrange them in a logical order. Some authors use an index card system in which each separate item of the proposed report is tabulated together with a paragraph describing the material that must be treated under that item. Other authors follow a similar method but use full sheets of paper for each subject and give a much fuller description of the material under the subject headings. The latter method puts you in a good position to complete the report in a short time: Each subject has been so fully expanded that the problem remaining is one of combining and rewriting the information contained on the separate sheets of paper. Others choose to do their outlining on a computer. Any of these methods permit you to note thoughts that occur during the course of writing one report section but that should be treated in other sections. Cultivate the habit of going to the original outline to record thoughts for later consideration.

Another useful purpose of the outline is to indicate the relative importance of headings. This relation can be shown by using a numbering system. (The numbers appear in the final report only when there is extensive cross-referencing.) Headings of equal weight, or importance, must be written in the same form. The order and form of the various headings used in NASA reports are

Main Heading

Subheading

Run-in heading.—This heading is indented on the same line as the first line of the paragraph.

> *Below run-in heading:* This heading is indented on the same line as the first line of the paragraph.

Three levels of headings should be sufficient; more may disrupt your readers' concentration. The typeface and placement of headings will vary with the type of publication.

Thorough outlining will make both writing and reading the report easier. Study your outline carefully to be certain that each item blends into a logical plan and ordered presentation.

4. Writing the Rough Draft

With a logically organized outline and the necessary illustrations already prepared, writing the rough draft should be much easier than you thought. But do not expect to write the final version in the first attempt. The rough draft should be the last of several versions, each an improvement of the preceding one. This final version is considered a "rough" draft because it still must go through a series of technical and editorial reviews. But it should be as polished as you can make it. From your point of view it should be ready for printing and distribution to a critical audience.

Try to start writing the first version of the draft immediately after completing the outline while the ideas developed there are still fresh in your mind. Write this first version as rapidly as possible. Concentrate on *what* you want to say rather than how to say it. Keep writing down the thoughts as they flow into your mind, following your outline. Avoid going back over what you have written until you are through writing. Then review this version—but only for its technical content. Are all of the ideas you wanted to express included? Have you included irrelevant ideas? Does the report organization still seem logical? Sometimes writing the first version will reveal some unexpected problems that require a change in the outline.

In the second version of the rough draft, writing style becomes important. With the technical content in a well-organized form from the first version, this is the time to concentrate on how you say it. Keep your readers in mind. Remember, your purpose in writing the report is to transmit the information needed to support your conclusions. To make sure your readers understand your conclusions, you must transmit your information clearly, logically, concisely, honestly, and tactfully.

5. Revising the Rough Draft

The last stage of report preparation, rough-draft revision, is just as important as the previous stages, but it is the one most scorned by inexperienced writers. Revising a draft is comparable to painting a house: the appearance is improved without influencing the structure. But a report's "appearance" (readability) may determine whether or not it is read.

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Before you can revise your rough draft, you must recognize that it is not perfect. Approach it with a critical attitude. This can best be done by setting the draft aside for a few days, or at least overnight. This time lag should give you a fresh viewpoint and allow you to change to the role of a reader. This change in roles is most important because you must try to see what is actually written rather than what you think you wrote.

Successful technical writers use a wide variety of methods to review and revise. One of the best involves three *separate* reviews of the report:

1. The first review is of the material in the report. In this check ask yourself these questions: Are the conclusions valid? Is sufficient information given to support the conclusions? Is enough background information given to explain the results? Have all irrelevant ideas been deleted? Are the illustrations pertinent and necessary?
2. The second review is of the mechanics and organization. Are the subject and purpose clearly stated? Does the report flow smoothly from topic to topic? Are the relations between topics clear? Is each illustration clear and properly labeled? Are all required parts of the report included?
3. The third review is of spelling and grammar (see refs. 1 to 6), particularly punctuation (see ref. 10 and NASA SP-7084) and sentence structure. Is each sentence written effectively? Are the sentences varied in length and complexity to avoid monotony? Are the words specific rather than vague? Have all unnecessary words been deleted?

Make sure you can truly answer yes to all of these questions before you consider your draft finished. Do not try to make one review do the work of three. Trying to cover too many categories in one review usually results in oversights and errors. Some common faults observed in rough drafts are (1) faulty grammar; (2) clusters of nouns and adjectives modifying a noun and conversely strings of prepositional phrases after a noun; (3) use of abstract nouns instead of action verbs; (4) nonparallel construction of words, phrases, and sentences in enumerations; and (5) more complicated phrasings than required. Carefully review your draft to make sure you have avoided these common faults.

Requirements of Reports

Regardless of the specific style used to prepare technical reports, four general requirements must be met to produce good reports: clarity, conciseness, continuity, and objectivity.

Clarity

The purpose of a technical report is to transmit conclusions and their supporting evidence. To do this, your report must convey your *exact* meaning to the reader. The text must be clear and unambiguous, mathematical symbols must be fully defined, and the figures and tables must be easily understood.

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Clarity must be met from the readers' point of view. What may be clear to you as the author may not be clear to your readers. Remember, you are intimately familiar with the work, but they are not. You must continually reexamine your rough drafts with a reader's critical eye. Readers will not tolerate confusion. They must never become uncertain about what you are discussing, why you are discussing it, or what your plan of presentation is. They will rebel if forced into these mental gymnastics. If there is any discontinuity without proper explanation, the average reader will lay aside the report for later reading. Once this happens, the chances are slight that it will ever be read. You usually have just one chance to sell the reader on the report's objectives. And that requires a presentation that is logical, simple, and systematic.

Conciseness

Most of your intended readers are busy. Therefore your reports should be concisely written. That is, your story should be told with the fewest possible words and illustrations. Help your readers by omitting everything irrelevant to the results and conclusions. Do not be disappointed if a report that describes a lengthy program is only a few pages long: Report quality is often inversely related to report length. Your readers will be interested in your conclusions and the supporting evidence and will want to get these as quickly as possible. They will not be particularly interested in any problems you had in getting the results. Explaining such problems usually just hides the important aspects of the report.

On the other hand, do not condense reports at the expense of your readers' understanding. Give enough information to enable them to understand clearly *what* you are describing and *why* you are describing it. Include enough background information to make the context clear. Do not assume that they will remember details of a previous report—or have even read it. Include all details needed to understand the current report. In short, make your reports brief but comprehensible.

Continuity

Reports should tell a complete story as logically and interestingly as possible. This requires continuity between succeeding sentences, paragraphs, and sections and between the written text and the figures and tables. Transitional words, phrases, sentences, or even paragraphs may be needed to lead your readers through the story. But overusing transitions can slow the pace of your narrative.

Carefully choose the places at which you refer to figures and tables to limit distraction. Making these references at the beginning or end of a discussion is usually preferable.

Objectivity

Technical reports should be objective and show restraint. Be honest with your readers. They will become suspicious if they detect hidden meanings or any type of subterfuge, and you will then have little chance of convincing them of your conclusions. They expect

you to evaluate the data honestly. Do not try to hide deficiencies in your research. No technical report is better than the research on which it is based. Tell your readers frankly what your assumptions were, what your probable errors are, and what you may not understand about the results.

In addition to being honest, be tactful. If you are faced with the problem of presenting technical results that may conflict with previous results or with the personal prejudices of some readers, refrain from making dogmatic statements and avoid sounding egotistical. Your readers will be persuaded by facts, but they may become irritated if you attempt to impress them with your cleverness or to claim credit for accomplishments. Write to *express*, not to *impress*.

Writing Style

Technical writers usually use a more formal writing style than do nontechnical writers. A degree of formality is required because the personal style of a technical writer must be secondary to the clear and objective transmission of information. Any injection of personality that obscures the exact meaning is undesirable. But this does not mean that technical writing has to be dull and rigidly stereotyped. All writers should strive to make their writing enjoyable to read. Therefore attempt to develop a writing style that is both clear and interesting.

This section includes some specific suggestions for developing and improving your writing style. For additional suggestions read some good books on technical report writing and grammar (e.g., refs. 1 to 6). Also, look up words in our online archives of our grammar and usage articles, Word of the Week and Quirks of English.

Writing Naturally

Imperative in developing a good writing style is writing naturally. Many technical reports are stilted and overly formal, examples of the "Official Style" discussed by Lanham (ref. 4). Authors usually do not speak that way, but they feel that technical reports must be written in that style. A stilted style is difficult to read and detracts from the contents.

To avoid a stilted style, write in a way that comes easily, using words and phrases that come naturally to you. Do not try to impress readers with your vocabulary, but be certain that the words you use convey your exact meaning. Your readers will be interested in what you have to say and not in how eloquently you say it. Avoid long, complicated terms if shorter and more familiar ones are available. But be careful not to use jargon because it may be misinterpreted.

Guiding the Reader

To achieve clarity and continuity in a report, you must carefully direct your readers' attention throughout the report. Many successful writers do this by using the three classic principles of presentation:

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1. Tell readers what you plan to tell them (Introduction).
2. Then tell them (main text).
3. Finally tell them what you told them (Summary of Results or Conclusions).

State your purpose or objective clearly and follow it with a concise description of the method you will use in presenting the subsequent discussion. Then proceed with your presentation, making certain that it is consistent in every respect with your plan. Finally summarize your conclusions and recommendations.

Getting to the Point

Technical reports are not mystery novels; get to the point as directly as possible. Do not lead your readers in and out of blind alleys before taking them to the final destination. Omit information that does not directly relate to the conclusions. Remember, readers are interested primarily in conclusions and supporting evidence.

If you must include some information or discussion that may be of interest but is not directly pertinent to your conclusions, put it in an appendix. Using an appendix allows you to bring up points that may be of interest to some of your readers without distracting the reader who is interested solely in your conclusions.

Emphasizing Major Ideas

Because the purpose of technical reports is to transmit ideas, emphasize your major ideas so that they cannot be missed. To do this, clearly subordinate any supporting information to the major ideas. The report outline is particularly useful here because it establishes the major and supporting points for each section of the report.

Your major ideas can also be emphasized by briefly stating them at the beginning of each section and then summarizing them at the end of the section. Emphasis can also be aided by careful use of headings.

Separating Fact From Opinion

Reports should clearly differentiate between facts and opinions. Many authors are remiss in doing this, overlapping discussions of their experimental results and the conclusions they have drawn. Carefully alert your readers when fact ends and opinion begins.

The statement of your opinions is an instance where the use of the first person is desirable. For example, if you follow the presentation of some specific results with "It is believed that . . .," your readers cannot be sure if this is your opinion or a generally accepted belief. To avoid this confusion, use the first-person pronoun to say, for example, "From these results I conclude that . . ."

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Data Presentation

Because most technical reports rely on figures and tables for the presentation of data, the form and quality of the figures and tables are important in establishing the style and readability of the report. Good judgment should be used in selecting both the data to be presented and the method of presentation. Use only figures and tables that add to the value of your report. Present the data as simply and straightforwardly as possible so that your readers can easily grasp the significant points. Present data in the text, or in a figure, or in a table—but never in more than one way.

Before beginning to write the report, carefully select the data to include. Most carefully prepared programs yield more data than are needed to support the conclusions. Including all your data in the report is unnecessary. Use only data that are directly pertinent to your conclusions, and do not try to impress readers with how much data you have collected. Quantity is no substitute for quality in presenting technical results.

Once you have selected the data to be included in your report, decide how they can best be presented. Should they be tabulated or plotted? To answer this question, consider your readers' needs. Do they need to know exact values? If so, tabulate your results. If relative trends are more important, use graphs. Both the figures and tables should be as self-explanatory as possible and arranged logically to tell the main points of your story without reference to the text.

Figures

The figures used in technical reports generally are of three types—graphs, drawings, and photographs. Figures are numbered with Arabic numerals in the order of their mention, unless the mention is clearly incidental. In the final report they are either inserted in the text near (preferably following) their first mention or grouped together at the back. Sketches are lettered consecutively ((a), (b), (c), etc.) if they are referred to more than once. Under no circumstances should the arrangement of black and white figures or the parts of one figure be out of sequence. Figures arranged in a group are in sequence from top to bottom or from left to right. Exceptions are sometimes made for color figures to reduce the number of pages printed in color.

Prepare figures with consideration for their appearance in the final printed document. The size of the printed figure including the legend (title) cannot exceed the dimensions of the report image area (7 1/8 by 9 1/8 in. in NASA reports). Within these limits various sizes, proportions, and arrangements of figures are possible. (A large, complex figure may be reproduced on facing pages.)

All figures must have legends; if a figure has parts ((a), (b), (c), etc.), it must have corresponding sublegends. Use similar wording in the legends of related figures. After you have assembled the rough draft of the report, thumb through the figures and tables, reading merely the title of each to make certain that the format and the nomenclature are consistent. Conditions applying to the entire figure or to a part are normally stated as part

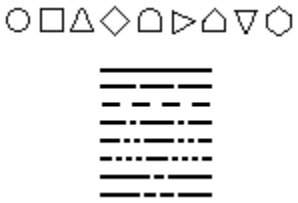
of the legend or sublegend. But when the same conditions apply, for example, to every graph in a report, they are best stated once in the text.

Graphs

Graphs should be clear and simple with as few data curves as possible. It is usually best to have no more than six types of lines or data points on a graph—four is better. Try to avoid interlaced or unrelated curves. As few words (labels) as possible should be inserted directly on the figure. Equations should be placed in the text, lengthy tabular material should be presented in a separate numbered table, and explanations and conditions should be added to the legends or placed in the text. (You can contact the Publishing Services Coordination Office to arrange to have the Graphics group prepare or adapt your figures.)

Choose coordinates that will give your readers a physical feel for the variables being presented. Clearly label what is plotted and the units used. Whenever possible plot all parts of any one figure or related figures on scales with the same increments. Label main and auxiliary scales with a word description of the concept or quantity, its symbol, and its unit. For example, "Axial distance, *x*, cm" is more immediately descriptive than "*x*, cm." Add auxiliary scales at the left and bottom of the figure if there are four or fewer scales. Place additional scales at the right or top. For ease in interpolation divide scales into logical, consistent increments. For example, when both U.S. customary and SI units are used, each scale must stand alone. Do not simply convert the values on one scale into the other system of units. Such a scale is useless to the reader.

Use the same data symbols and lines to represent the same conditions consistently throughout the graphs of your report. The following data symbols and types of lines are commonly used:



Do not use the symbols + and x on figures with grid, and avoid solid or partly solid symbols if symbols overlap. The curves and data points may be identified by keys or labels. Keys are preferred when several curves must be distinguished or when several conditions are associated with each curve. Keys generally follow the format for tabular material and should be consistent throughout a set of figures.

Drawings

When you use drawings or sketches to illustrate test equipment, try to keep them simple. Include only those features of the equipment that are essential to your readers' understanding, and avoid unnecessary detail. Arrange with the Publishing Services

Coordination Office for complex drawings to be prepared by a technical illustrator while the report is in the rough-draft stage, if possible, to allow adequate time for the illustration to be prepared.

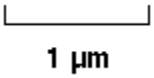
Photographs

When your research project has "jelled," consult the Imaging Technology Center concerning the best way to record the data photographically, if applicable, and to show your apparatus and research facilities to the best advantage. Photographs of similar objects should be sized for compatibility. Glossy prints taken with black-and-white film reproduce best. Prints that have already been screened are not usable. The use of color in printing is discouraged because it greatly increases publishing costs.

Do not include a photograph of equipment which is so elementary that a sentence would describe it. Label the most important features being shown. Remember, equipment that seems simple to you may be complex to readers who are not familiar with it. Limit the labeling and the field of view to the main items discussed to avoid confusing readers with extraneous items. Mark up a copy of the photograph rather than the glossy print.

If your photographs are Polaroid prints, have negatives and additional prints made before submitting them for use in a report, for slides, etc. You are then protected in case of damage or loss, and prints are readily available for additional uses.

Include some object or scale in the photograph to help your readers judge the size of the objects shown. For photomicrographs and electron micrographs, use a scale instead of stating the magnification:



(The size of photographs is often changed in reproduction, rendering the magnification meaningless.)

Tables

Tables are often included in technical reports to present data in an exact, highly concentrated form. But because tabulated data are so concentrated, many readers have difficulty grasping their significance. Tables are therefore the least preferred method of transmitting results to readers and should be used only when absolutely necessary. When you use tables, make them as brief and simple as possible. Otherwise your readers may not bother studying the detailed columns of figures, and you will have wasted your time in presenting the data. "Whenever a table, or columns within a table, can readily be put into words, do it" (ref. 2).

Tables are numbered in the order of their mention, in Roman numerals except when a report contains 20 or more tables. Then Arabic numerals are used. Similar data at

different conditions are organized into parts ((a), (b), (c), etc.) of the same table with subtitles. Numbered tables must have titles.

Present tabulated material in an organized manner. Like elements should read *down* not across. Variables are usually given in columns topped by boxheads, with the constants given in the first, or stub, column. Boxheads should be brief; if necessary, they may be amplified by footnotes. Boxheads usually contain a word description of a concept or quantity, its symbol, and its unit, separated by commas; symbols must be defined when they are used. Arrange tabulated data in a logical order that your readers can easily recognize. Usually this arrangement is an ascending or descending order of value for the prime parameter. The order is necessary to clarify trends. You can also help your readers see relations and comparisons of data by carefully wording the boxheads and the stub column. Put items to be compared in adjacent columns. Generally numbers in columns are more easily compared than numbers in rows. Another type of table is the leaderwork table, in which dissimilar data are listed in rows with leader dots connecting each parameter with the corresponding value.

Give conditions that apply to an entire table in a headnote. Indicate footnote citations by lower-case letters (superscripts) ordered across the table from left to right and top to bottom.

Technical Film or Videotape Supplements

Where data can be more efficiently presented or concepts explained through motion pictures, consider the use of a technical film or videotape supplement to your report. For expert production assistance consult the Imaging Technology Center's video department. These films and videotapes are described in a catalog (ref. 7) and made available on loan for nonprofit, noncommercial screening. (Catalogs of recent NASA Glenn and NASA-wide videos are available on the WWW.) Many requests are received from universities, industrial firms, and Government research organizations.

Microfiche Supplements

A microfiche supplement, like a technical film or videotape supplement, can make available considerably more graphic and textual information than the basic research document. Microfiche supplements are typically used for extensive sets of tables or figures and comprehensive bibliographies.

CD Supplements

CD supplements, to document lengthy material electronically instead of in printed form, can be ordered through the Imaging Technology Center.

Miscellaneous

Computer Programs

Reports and papers should not include computer programs. Computer programs are to be distributed by the Computer Software Management and Information Center (COSMIC), a NASA facility at the University of Georgia. In order to ensure and expedite the availability of a computer program to U.S. users, obtain a LEW-number from the Commercial Technology Office before submitting the publication to Publishing Services for processing. (Reference the LEW number in the report.) The Commercial Technology Office will prepare a Tech Brief and send it and the program to COSMIC.

Trade Names

Use of trade names is discouraged because NASA considers it improper to advertise, endorse, or criticize commercial products in its publications. Use generic names whenever possible. Trade names may be used if their use is the only way to specify material or equipment that is necessary to reproduce the results. The first appearance of a trade name in the text must be accompanied by the name of its registered owner (e.g., International Nickel Co., Inc., IN738). But the symbol for a registered trademark (an R inside a superscript circle) is not used. Those reports using trade names must include a trade name disclaimer:

Trade names or manufacturers' names are used in this report for identification only. This usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

The disclaimer is printed on the back of the title page of a NASA-series technical report or as a footnote to the title of a journal article or technical society presentation.

Spelling

The authorities for spelling in Glenn reports are the NASA Thesaurus (ref. 8 or online version), Webster's New Collegiate Dictionary (ref. 9), and the Government Printing Office (GPO) Style Manual (ref. 10). The GPO Style Manual is also a guide for punctuation, compounding words, and capitalization.

Numerals

For ease in reading numbers of five or more digits, group them in threes from the decimal point, separated by spaces instead of commas. In a column of numbers add the space to all numbers if at least one number in the column has five or more digits to the left of the decimal point—for example,

10 091

Otherwise close up four-digit numbers in columns.

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Rough-Draft Typing

Most rough drafts are typed by the author or in the research branch or division office. When submitting your report to the Publishing Services Coordination Office, provide the diskette and a *double-spaced* hard copy. Indicate the word-processing and graphics programs used, including the platforms. If the rough draft cannot be typed in your division, the Publishing Services Coordination Office will arrange for word-processing (see Manuscript Services). Clearly mark handwritten material, particularly equations, so that the computer operator will understand what is meant. Identify such symbols, as well as handwritten Greek or unusual symbols, the first time they are used. (This advice applies equally to figures and slides, especially if they will not be edited.) Writing text on every other line (double spaced) will also help the computer operator.

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Report Introduction

The importance of the Introduction in all forms of exposition is that it prepares the reader to receive, with the greatest economy of effort, what the writer intends to present. Reports, like any form of exposition, attempt to make information and ideas clear and convincing. The Introduction permits you to launch immediately into the task of relating your readers to the subject matter of the report. Specifically the Introduction makes clear the precise subject to be considered, indicates the reasons for considering the subject, and lays out the organization and scope of the report. This is where you tell the reader what you plan to tell and why and how you will tell it.

The Introduction should focus your readers' attention on the subject to be treated. It should enable them to approach the body of the report naturally and intelligently.

Your prospective readers and subject material will influence both your point of view in writing the Introduction and the amount of material you use. The union of reader and subject must be achieved with a firm, but not heavy, hand. Readers should never be confused, unpleasantly surprised, or disappointed with what they are told throughout the report.

This chapter considers the relation of the Introduction to the rest of the report, describes the functions of the Introduction, and discusses its style and length.

Relation to Rest of Report

The Introduction makes clear how the body of the report will develop. For example, it answers these questions: Were data produced and analyzed and the results summarized? Were conclusions drawn? Was there an initial theoretical model? Or was there a subsequent analytical model? Did the data create a new understanding? Is the report only an analysis? Are comparisons made?

The style and order of thinking, or logical arrangement, in the Introduction should be consistent with those in the main body of the report.

Primary Functions

Statement of Subject

The first function of the Introduction is to identify immediately and unmistakably the exact subject of the report. *What* is going to be considered in the report? It is necessary to define and bound the subject in order to guard against misunderstanding. For example, a report dealing with the effect on combustion efficiency of a single design idea tried through six modifications in a turbojet combustor should not pose as a report on combustion, nor on turbojet combustors, nor yet on the effect of turbojet combustor design on performance. What the reader must know is that the report describes the effect

of such-and-such a design idea on the combustion efficiency of a turbojet combustor—no more, no less.

Statement of Purpose

A second, and equally important, function of the Introduction is to state clearly the reasons for discussing the particular subject. Just *why* was the report written? It should indicate the importance of the subject to the reader, relate the report to previous and similar work, and make clear your objective.

The importance of the subject will vary widely in NASA reports. Putting the subject matter in its proper perspective requires a broad knowledge both of the state of the discipline (including pertinent literature) and of the readers who will use the report. It also calls for finesse in writing. Some of you have seen your supervisors struggle with your writing to try to introduce this matter of perspective. Most Glenn reports are incremental bits of information to a field of knowledge; all too often this information can barely stand alone. The danger here is misuse of the data through overgeneralization. On the other hand, it is equally wrong to report factual information with no effort to point out such significance as it may have in its field or related fields. There is a narrow course between overgeneralization and noncommunication.

The extent to which background is given depends largely on the type of paper being written. Often a few key references are available to tie the new work to what preceded it and to the few studies that it touches immediately and directly. Summary papers that establish stepping stones in the advance of a field help relate increments to the background. The occasional major paper that starts a new field demands a broad perspective from the author in relating the new field to other fields and in relating the new field properly to aerospace.

The purpose that you express in the Introduction must be shaped by consideration of your readers. Why should they read the report? What good will it do them?

Statement of Organization and Scope

A third primary function of the Introduction is to lay out the organization that will be followed in the report. Just how is your subject going to be discussed? Give your readers a look at what lies ahead; furnish them an itinerary.

Also your readers should know at the outset the scope and limitations of the work. For example, if design features for a high-performance rocket engine are to be reported, it is important whether the work was done in 100-, 10 000-, or 100 000-lb thrust engines and what propellants and chamber pressures were used. Describe special theories, new or unusual procedures, unique equipment or ideas, anything that contributes to the uniqueness of the subject, so that your readers can orient the report to their special interests and needs.

Secondary Functions

When the place or places where the research was conducted are not adequately designated on the title page or cover, they may be designated in the Introduction (or in the Apparatus section). The Introduction should mention unusual aspects of a report, such as a film, videotape, microfiche, or computer program supplement, a supplementary report, or an appendix prepared by another author. Use of dates in the Introduction is generally necessary only when a long delay in reporting is encountered or where publication is in a highly competitive field of research and a scoop or patent is involved.

Style and Length

The Introduction may vary in style quite widely within certain bounds. The limits imposed are that the language be clear, direct, and accurate. Within these limits you are free to exercise your art. Indeed you must exercise it if the needs of your readers are to be fulfilled. The task is rendered fairly easy in that the Introduction is not highly formalized. Its three primary functions should not be reeled off in 1-2-3 order, "The subject is . . ," "The purpose is . . ," "The organization and scope are . . ." Instead they should be built into a few paragraphs of expository writing in a style that will be both pleasant to read and unmistakably clear.

One outstanding rule for the style of the Introduction is to construct the first, or theme, sentence so that attention is deftly, decisively, and immediately focused on the precise subject to be treated and, if possible, on the method of approach. Again, keep your readers' viewpoint uppermost in mind. The ease of writing this sentence is in direct proportion to the clarity of the subject being presented. Where you have a clean-cut, definite accomplishment to report, the theme can be stated easily. But if the work has wavered and wobbled and wandered and there is scarcely a definite piece of information to be gleaned from it, the theme can be stated only with great difficulty, if at all. These remarks about the ease or difficulty of writing a striking first sentence apply to the entire Introduction and even to the entire report. Keep that in mind as you plan and conduct your research.

Many find the Introduction difficult to write. All these requirements may seem to make it even more difficult. The best way to write it is to become familiar with the report matter, plan what to put in the Introduction, and then start writing. Try to explain the story to be told in the report: what it is about, why it is being told, and how it will be told. Seclude yourself from interruptions and write continuously—go with the creative flow. Then criticize and revise your work. You may need to rewrite the Introduction and the theme sentence several times.

Because you are writing for readers who will have some reason for using your report, good background on your potential readers is obviously desirable. As you work and grow in a field, learn about others in the field—what they have done and are doing and what they have published. Also build sufficient background about your field and related fields

so that you know almost by instinct what work is needed in it and what is not, what is timely and important and what is not, what is new and what is not, and what will earn you and NASA respect and appreciation and what will not.

About 200 to 300 words is the usual length of an Introduction—a page, more or less. The length really depends on how much background must be given, and that depends on the kind of report. In major papers on new ideas the Introduction may be several pages long. If considerable amounts of background information must be included for your readers, try moving it from the Introduction to a separate section of the report (e.g., entitled "Theory").

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Experiment and Analysis Descriptions

Most NASA reports include one or more sections immediately following the Introduction, or the Symbols section if there is one, that describe how the research or analysis was performed and what types of equipment and materials were used. A precise record of the procedures used is vital in establishing the validity of the results.

This chapter gives the format of the experiment and analysis descriptions as well as information on symbols, units, and errors and precision.

Format of Experiment Descriptions

The format of experiment descriptions varies greatly with the type of work being reported. For example, a report on an experimental program may have separate sections entitled "Apparatus," "Test Procedure," and "Test Specimens," or it may have one combined section entitled "Apparatus and Procedure" with appropriate subsections.

The extent to which the descriptive material is divided by subheadings depends on its complexity or length. Unless the description is brief, the use of subheadings will be extremely helpful to your readers. New and different equipment or procedures require more detailed description than if they are standard. When possible, construct subheadings that relate to those used in the Results section.

It is usually best to describe first the whole and then the parts. Organize descriptions so that statements need not be repeated to bring out associated material. Give enough information directly, or indirectly by reference, so that your readers could reproduce the experiments. Refer where necessary to previous reports, but do not reference another report for one sentence of additional description.

Apparatus Sections

Test facilities section

Generally a new test facility should be described in sufficient detail that its essential workings could be reproduced. A good initial description that can be referenced may greatly simplify future reports. Be sure to note special mechanical devices used. Use photographs and diagrammatic sketches with adequate notation. Try to use standard, accepted terms for equipment, but avoid trade names.

If the basic facility has been adequately described in a previous report, do not repeat the detailed description but reference that report. In your report give the reader just enough information to visualize the equipment. Sometimes reproducing a figure that shows the equipment layout is desirable. Describe any important modifications to the original facility.

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Instrumentation section

The discussion of instrumentation may be organized according to normal flow paths through the test facility or according to particular types of instrumentation. Photographs or drawings of the test facility may show the position of instruments, such as thermocouples, pressure tubes, cameras, photoelectric cells, and sampling tubes. A specialized instrument may require more detailed description and additional drawings. The design of instruments may be illustrated with a sketch or referenced to previous work. Commercial instruments are usually described only to the extent necessary to duplicate the results (e.g., "self-balancing potentiometer," "calibrated rotameter," or "flat-plate orifice installed according to ASME specifications").

Materials Section

In reports describing the testing or evaluation of materials, the test materials should be characterized in detail, including the purity of the material, its grain size and density, the method used to produce it, and its thermal history prior to testing. These characteristics are needed to compare the test results with other data on similar materials.

Test Procedure Section

In describing the procedures used in a test program, it is helpful to begin with an introductory paragraph that describes the kind of data obtained in the program. If the procedures used were numerous and complex, summarize them in the introductory paragraph.

The conditions studied can usually be described clearly in a few sentences but may be sufficiently numerous or complex to warrant listing them in a table. State your reasons for selecting these particular conditions.

Describe the test procedures in enough detail that your readers can judge the value of the results and could repeat the experiment. If the procedures are detailed in other publications, reference them and only briefly describe the major steps. Always include enough description to give an overall picture of the operation. A unique operation will require more detail.

Where the calculations performed in analyzing the test data are conventional, it is usually sufficient to reference the type of analysis made and merely include the final equation (or equations) used. Describe nonconventional or little-known analytical methods in more detail. When these methods are lengthy or complex, a sample calculation would be helpful to most readers. It is best included as an appendix.

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Format of Analysis Descriptions

If a report presents the results of a theoretical analysis, the experiment description section is replaced by a section that might be entitled "Analysis." If the analysis is lengthy, the details may be included as an appendix. The Analysis section in the main text then includes (1) a statement of the problem, (2) the assumptions and limitations of the analysis, and (3) a brief description of the general analytical method. (Refer your readers to the appendix for details.)

In preparing an Analysis section note the following items:

1. All numbered and most unnumbered equations are centered between margins and set off from the text by spacing.
2. An equation and the introductory material that directly precedes it should be presented in correct grammatical form. The introductory material may be followed by a colon, a comma, or no mark of punctuation.
3. Equations needed for later reference are numbered (1), (2), (3), etc. Identification such as (1a) and (1b) may be used for equivalent or derivative equations. A brace may be used to connect a group of equations with the same number. Equations in appendixes are usually numbered according to the appendix in which they appear ((Al), (A2), (Bl), (B2), etc).
4. When a numbered equation is repeated, it retains its original number. An equation given more than once should be repeated in exactly the same form.

Symbols Section

Use consistent mathematical notation throughout a report. Because many symbols have different meanings in various fields of science, define all symbols used in a NASA report, including those in figures and tables. If only a few symbols are used, define each in the text as it first occurs. If many symbols are used, group their definitions in a separate section entitled "Symbols." This section directly follows the Introduction or is either the first or the last appendix. Make a symbols list an appendix when it contains more than 30 symbols, when the symbols are used mainly in the appendixes, or when some or all symbols have been used and defined only on the figures and tables.

List symbols in alphabetical order with English symbols preceding Greek symbols. These are followed by subscripts and then superscripts. Capital symbols precede corresponding lowercase ones. Do not define mathematical conventions such as d, exp, and - (bar). When subscripts or superscripts apply to several main-line symbols, do not define them with each symbol but list them separately. Explanatory information (such as formulas or units) follows the definition. No symbol may be used for more than one concept, and usage of symbols and units must be consistent throughout the text, appendixes, tables, and figures. Use symbols that are conventional in your particular field of work.

Define acronyms, initialisms, abbreviations, and the symbols for chemical elements and compounds at their first occurrence in the Summary and again in the main text (e.g., monolithic microwave integrated circuit (MMIC)). They are not defined in the Symbols section. Chemical names are preferably written out throughout the text except when formulas are used or the terms appear frequently.

Abbreviate units after numbers, but write them out otherwise.

Errors and Precision

In any report concerned with numerical values, the accuracy, precision, and reproducibility of the data presented must be clearly stated. Discrepancies within the data should be explained. This material fits best in the Results and Discussion section if based on a comparison of duplicate test results and in the Test Procedure section if based on instrument calibration data. The experimental work must obviously be planned so as to yield the necessary data on accuracy, precision, and reproducibility. Day-to-day check tests at identical test conditions and periodic calibrations of instruments are necessary parts of most experimental programs.

When the terms "accuracy," "precision," and "reproducibility" are used, their exact meanings should be clearly stated, for such terms have different connotations to different people. Accuracy usually denotes the absolute correctness of the determination; precision generally denotes the extent to which a result is free from random accidental errors. A result can be very precise (i.e., all measurements agree) but also inaccurate because of inherent errors in the measurements. Reproducibility denotes the agreement, or lack thereof, between values obtained in like determinations at different times during the test program. Poor reproducibility may be the result of either the precision or the accuracy.

A discussion of accuracy should contain an analysis of possible errors involved in individual measurements and how these errors are reflected in the final results. This is generally expressed as the "maximum probable error." A discussion of precision usually involves comparisons of duplicate results, and the precision is generally expressed in terms of a "deviation." Use standard methods of computing probable errors and deviations whenever possible, and indicate for your reader the methods used.

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Results and Discussion

The presentation and discussion of the results is the heart of the technical report. Many readers, of course, are interested only in obtaining the quick review of the work afforded by the Summary and the concluding section. But readers who have reason to study the entire text of a report will normally spend most of their time on the Results and Discussion section.

The first purpose of this section is a well-organized and objective presentation of the results. Tables and figures that show the results should have sufficient supporting description to permit the reader to interpret them quickly and accurately. But do not repeat in words what is already apparent from examination of the tables and figures. The second purpose of this section is a discussion of the results, together with their analysis, to show that the conclusions are warranted. Each major conclusion should be clearly explained and compared with the results of similar work by other investigators.

This chapter describes the mechanics for achieving these purposes. The organization, the methods of presentation, and the discussion of results are described. Several examples illustrate the principles involved.

Organization of Section

The Results and Discussion section should present the data as concisely and clearly as possible. To achieve this goal, prepare a good outline of this section before starting to write.

Conventionally, an introductory statement is used to remind readers of the type of tests conducted and the scope of the investigation. Any other statements necessary for correctly interpreting the results should be made in this introductory paragraph.

An important decision is whether to present this material as a single section or as two separate sections, one entitled "Results" and the other "Discussion." Regardless of the length of the report, a single section combining the results and their discussion is usually preferable because this scheme is clearer and less repetitious.

Separate sections may sometimes be desirable:

1. *When heterogeneous data must be considered in making a point in the discussion*

For example, the use of separate sections may be better when reporting test data on several materials to determine which is best for a particular application. In this case the test results for each material would be presented in the Results section. The Discussion section would then be used to compare the properties of the various materials, to review

their advantages and disadvantages for the application being considered, and finally to select the best material.

1. *When a large number of similar curves must be compared on a single figure*

If your data fall too close together to be presented on a single plot, you can present the original data in separate figures and later combine only the faired curves (using different types of lines) from these figures on a single figure for comparison and discussion. The report may well be written with these two sections separated. A lengthy presentation of results about which there is little or no discussion is best made in an appendix. Then only the comparison figure need be shown in the Results and Discussion section, with reference made to the appendix.

If this section is longer than approximately one page, use the pertinent subheadings determined during your preliminary outlining. Perhaps the most frequently used type of outline groups similar data. Another type of outline groups the data obtained with each of several systems being compared.

Avoid promises of NASA research to be published and references to work in progress. Such suggestions in no way enhance the value of the report and might stimulate inquiries that could prove embarrassing if redirection of a worker's activities leaves such promises unfulfilled. If results indicate the need for further research, a simple statement to this effect should suffice.

Presentation of Results

Data should be presented as clearly and simply as possible. Although you are familiar with the work, others are not. Avoid taking too much for granted; avoid complicated correlations; avoid making the presentation too long and too involved with insignificant details. First present the data in a simple, readily understood form. Then if necessary, give complicated comparison figures or correlation curves that make sense only to those fully familiar with the field. In preparing the figures and tables take care to put them in acceptable form.

Including a summary data table is sometimes desirable. The table should include the data necessary for your readers to evaluate the accuracy of your plots and correlations. Additional data may be included to enable them to devise additional plots and correlations. For the sake of brevity present only the most important data in the summary table. But if calculated data are very important and are widely used in the report, include them in the summary data table even though the reader could obtain these values by independent calculations.

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Discussion of Results

The discussion of the results is one of the most important parts of a technical report. To discuss the results adequately, you must clearly understand their significance. This requires that you have mastery of the theory pertaining to your field and broad knowledge of the information already available from work in this and allied fields. The discussion must clearly point out the exact contribution made to the existing fund of knowledge by the new data. If the results have an immediate application, point this out. If possible, give an example to illustrate the method of application. Clearly state any significant conclusions and either prove or properly qualify them. But discuss the results; do not merely recapitulate them. The major results and the conclusions, normally stated in both the Summary and the concluding section, must be clearly established here.

Any new or unusual result should be explained. If you do not understand the phenomenon or if the data are too limited to permit rigorous analysis, it is sometimes worthwhile to present a speculative discussion outlining several possible causes. Alert your readers that such a discussion is speculative.

The discussion of the results sometimes includes the method of computation or derivation, normally presented in the Analysis or Procedure sections. Such situations may arise when one figure is derived from preceding figures. If the method is involved, include a complete example as an appendix and indicate only the main steps here.

Again, judgment must be exercised to achieve the desired result. Essential information must not be kept from the reader. But trivial details must be subordinated by placing them in an appendix to avoid diluting the text and obscuring the important facts. End the discussion with a short summary explaining the significance of your work. "When you describe the meaning of your little bit of truth, do it simply. I believe that the simplest statements evoke the most wisdom; verbose language and fancy technical words are used to convey shallow thought" (ref. 2).

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Concluding and Supporting Sections

This final chapter on the mechanics of report writing is a catchall in that it encompasses all parts of a report not previously discussed: concluding section, Summary, Abstract, title, appendixes, and references.

The concluding section is where you tell your readers what you have told them. It is also the section usually examined first by the prospective reader with limited available time. The Summary and Abstract are concise recapitulations of the report content. The title is the "punch line" and is most effective when short and informative. Each of these parts is important because of its potential to reach a different group of readers. Each should be written clearly and concisely.

Concluding Section

It is common practice in NASA reports to end the main text with a concluding section. In spite of skillful writing the reader may become confused or overwhelmed by the large number of details in a complicated report. Clearly the writer needs to bring out the most important facts and discuss their significance. Many busy people read the concluding section of a report first. On the strength of this reading they may become interested in the details, or they may discard the entire report. Therefore, the concluding section must be self-contained and independent of the main body of the report. Preferably it should be so worded that a person not completely familiar with that particular branch of science can understand what was learned from the investigation.

"Summary of Results," "Conclusions," and sometimes "Concluding Remarks" are the common headings for this section. These headings connote somewhat different contents distinguished by the degree of generality and certainty of the material included in them. Since statements made in this section are often quoted by other investigators, each statement should be critically evaluated for accuracy and clarity. A useful stage-setting approach to the concluding section is to briefly state the purpose and scope of your work.

A few ground rules should be observed in writing the concluding section:

1. Do not use undefined symbols.
2. Do not cite equations, tables, figures, references, and appendixes.
3. Do not introduce new material.

Summary of Results

The Summary of Results is the most straightforward concluding section. It simply restates the major findings of the investigation. All of the material presented must have appeared in the main body of the report. A frequently used method is to itemize the main factual results, usually in single sentences. The facts given are supplied from experimentation or theory—but not from any reasoning (i.e., they are not deduced).

Conclusions

A Conclusions section allows the inclusion of "deductions." The usual form of reasoning in reports is to draw a conclusion from a series of facts. Conclusions should be general: They should not depend on the particular apparatus or conditions of the report. If more than one conclusion is drawn, present them in the order of importance.

After the conclusions are written, examine every word and sentence critically to ensure that it means what you intended it to mean. Do not "conclude" already known facts. Do not confuse conclusions with results.

Concluding Remarks

When it is not possible to draw adequate, clear-cut conclusions, a Concluding Remarks section may be used. With this approach you are not constrained by the connotations of the headings "Summary of Results" and "Conclusions." You are free to give opinions, to evaluate, and to recommend. Of course the views you express should be based on the information provided by your investigation.

Sometimes both a Concluding Remarks section and a Summary of Results section are used. Dual concluding sections allow a concise summary of the major results as well as speculation or recommendations. When both sections are used, the Concluding Remarks usually precedes the Summary of Results as a "further discussion" of the results.

Summary Section

The Summary is the first main section in a NASA report. (Although this section appears first, it is usually written last.) In many respects the Summary is an abstract of the Introduction and the concluding section. The Summary is limited to 200 words. The concluding-section ground rules also apply to the Summary, which must be written so that it can be read independently of the report. It should be a concise recapitulation of the report content.

No specific format is prescribed for the Summary. Consider including the purpose and scope of your work (noting whether it is experimental, theoretical, or both), the range of variables, any limitations, and the major findings. Obviously results and conclusions given in the Summary should be consistent with those in the concluding section.

Abstract

All NASA reports must contain a brief Abstract. It appears on the report documentation page (RDP), which faces the back cover, and in library abstracting services such as Scientific and Technical Aerospace Reports (STAR). Abstracts are retrievable by technical automated online systems such as RECON, the CASI Technical Report Server, and the Glenn Technical Report Server (GLTRS). The Abstract must be understandable

independently of the text and should be **no longer than 200 words. But if you can tell your story in 50 or 100 words, do not use 200.** The Abstract should briefly state the main features of the report such as the purpose, scope, and major findings. It is a condensed form of the Summary. Because the Abstract and Summary are used for different purposes, repetition in these two sections is acceptable. The Abstract of a classified report must be unclassified.

Many readers are first informed of your report through abstracting services. In fact, the Abstract usually receives wider circulation than the report. Therefore take the time to word the Abstract carefully so that the true nature and content of your report are described.

Title

Webster says the title is "the distinguishing name of a written, printed, or filmed production." Clearly this statement is appropriate to titles of technical publications. Much abstracting and indexing is based on the title. "An improperly titled paper may be virtually lost and never reach the audience for which it was intended" (ref. 2). For this reason alone the title must be carefully thought out and worded to convey the most information in the fewest words (maximum length, 120 characters including spaces).

Identify the basic area of effort and, if possible, convey either explicitly or implicitly whether the work covered was primarily experimental or theoretical. But avoid starting your title with, for example, "Study of . . ." or "Research on . . ." Do not use part numbers in titles (e.g., I, II, etc.) unless at least the first two parts can be published concurrently or nearly so.

If a report has been published in some other form, include that information on your rough draft. Depending on the type of publication, this information will be presented as a footnote on page 1 or in block 11 of the report documentation page. For example,

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*Published in part in the Welding Journal, vol. 43, no. 9, Sept. 1985, and presented at the October 1984 Meeting of the American Welding Society.

Judicious use of footnotes may be made in the text, but remember that footnotes are disruptive to readers and decrease their comprehension. Bibliographic references must not be given as footnotes. (See the section on references.)

Prepare a list of several tentative titles as you write the report, but make the selection only after all writing has been completed. By that time you will have had to ponder all aspects of your work and will be in the strongest position to choose a representative title.

Acknowledgments

Significant contributions directly related to the substantive content or preparation of a NASA technical report by individuals other than the authors shall be suitably acknowledged. When an acknowledgment of contribution is warranted, it is included in a paragraph on the back of the title page.

Appendixes

An appendix should be regarded as the place for material that is important, but not essential, to the complete development of the report. Examine the main parts of your report for unusually long and detailed sections. Frequently, the report can be improved by relocating some material from these sections to an appendix. Particularly appropriate for appendixes are

1. Involved mathematical derivations
2. An example of an analysis described in the report
3. Detailed descriptions of novel techniques, procedures, or equipment not essential to the main purpose of the report
4. Symbol lists

Appendixes must have titles. If there is more than one appendix, identify them by capital letters (A, B, C, etc.) in the order of their mention in the report. (Each appendix should be referred to at some point in the main body of the report.) If the symbol list is an appendix, make it either the first or last appendix. Numbering of figures and tables mentioned for the first time in the appendixes is a continuation of the numbering in the main text. Equations are usually numbered according to the appendix in which they appear (e.g., (Cl), (C2), etc.) but may be a continuation of the equation numbers in the main text.

Appendixes may be written by authors other than those of the report. Appendixes having independent authors are mentioned in the Introduction in the following manner:

Appendix B by John Z. Doe describes the computer program used in the analysis.

An author and affiliation line, as applicable, also appear under the appendix title.

References

References are citations of work related to points brought out in the report and are given as sources of additional information for the reader. The question of whether a reference is needed can only be answered with experience. A reference may be appropriate

1. To show work pertinent to the subject
2. To acknowledge the work of others in the same field, particularly quotations
3. To save repetition of lengthy descriptions of apparatus or procedures, development of theories, or other information
4. To support your assumptions, reasoning, viewpoints, or explanations
5. To compare previous results with those of your report

Reports, books, papers, and other publications referred to in NASA reports are listed in the References section at the end of the text, after any appendixes but before tables or figures appearing at the back of the report.

Format

References are generally put into established NASA style and listed by number in the order of mention in the text, tables, and figures consecutively. But the style and format of the reference list may follow accepted practice in the discipline of the report.

If you prefer, you may use the name (date) style of citation (e.g., Anders (1971, 1972); Smith (1974)). This style allows you to revise your manuscript without searching for and changing all reference numbers. This type of reference list is alphabetized by the last name of the first author. Multiple publications by the same author (or authors) are listed in chronological order from oldest to most recent. Documents by the same author in the same year are cited by author, year, and letter (e.g., Robinson (1970a,b)). Documents having no personal author may be cited in the text by using an abbreviated title.

If a bibliography is presented in addition to or in place of the References section, the publications in it are neither numbered nor cited in the text and are either listed alphabetically according to author, listed chronologically, or grouped according to subject.

Suitability

Only material that you have seen should be referenced. If you cannot obtain the original material, you must list the secondary source, but you may mention the original source in parentheses.

When surveying the literature for source material, check its availability. Do not use material that is not readily obtainable. Personal communications and papers "to be published" may not be included in the reference list of NASA reports but may be acknowledged with a parenthetical note in the text. In the note give the author's name, the date, the company name and location, and the status of the information (e.g., J.C. Jones, 1985, Acme Co., Philadelphia, PA, personal communication; P.D. Smith, 1986, J. Phys. Chem., to be published). Not-yet-published Glenn reports may be cited in the reference lists of published NASA reports if they have received the division chief's approval for final processing as NASA publications and have been assigned a NASA report number.

Chemistry 340 Spring 2004
Handout on writing technical reports

Limited-distribution documents, unclassified reports whose availability is restricted by Government regulations concerning the export of technology, should not be referenced unless absolutely necessary. If you use such references in a report with unlimited distribution, you will need to provide the name of the division, branch or office that controls the distribution of the report. (See refs. 11 and 12 for more information.)

Copyrighted material may be referenced without permission from the copyright holder, but you must obtain permission for direct quotation or reproduction of any part of such material. To avoid delaying the report, ask the NASA Glenn Library to contact the copyright holder as soon as you decide to use the material.

Documents of higher classification than the report may be cited in the reference list both as an acknowledgment of the contributions of others and as a courtesy to those with access to these documents. But *neither* the document title *nor* material or data from the referenced document may be quoted or discussed if they are classified higher than your report.

Correct citation of a reference is an important responsibility of the author. Double check the final draft of your report to make certain no errors have crept into the reference list.

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Review of Reports

Report review refers to the process wherein the proposed report is examined in detail for both its technical content and its composition by the author, the author's supervisors, and the technical review committee or a single reviewer. A published report not only represents an author's contribution to the scientific community but also reflects the fact that the contribution has the full support of NASA. Effective review of a proposed report is consequently of considerable importance both to the author and to NASA. All participants have a responsibility to do a thorough, effective, and expedient job. For some basic guidelines on publishing NASA reports, see the NASA Publications Guide (ref. 13) and Technical Publication Policy (ref. 14). For some basic guidelines on reviewing reports, see Technical Review Committee Guidelines

Steps in Review

A Glenn report generally passes through four reviewing steps before it is submitted to the Logistics and Technical Information (can be accessed at http://ltid.grc.nasa.gov from computers in the grc.nasa.gov domain only) Division's Publishing Services for processing and publication. (See the Research Publications Processing Guide (ref. 11) and FAQ—Publishing Your Technical Report at NASA Glenn Research Center for more detailed information on processing. The major steps in reviewing Glenn reports are

1. Review of rough draft by branch chief
2. Review of rough draft by technical review committee or single reviewer
3. Approval of rough draft by branch chief
4. Approval of rough draft by division chief

The nature of the report or your division's review policy may cause minor variances.

Prompt handling at each step is essential to minimize the total time involved. A good job of preparation and review by the author followed by a thorough check by the branch chief can save considerable time and effort in the subsequent steps. In particular, a detailed review of the technical accuracy and emphasis can save time in the originating division's reviews, and care in preparing and checking the figures and tables can save time in Publishing Services' preparation of the final report figures and tables.

Author Review of Rough Draft

Evaluation and review of a report must begin with the author. If you develop the ability to criticize your own material effectively, the need for later review and evaluation will be minimized. There obviously would be little need for technical review committees if reports were thoroughly examined by the authors. Many times failure to review a report effectively can be attributed to the tendency of many authors (and supervisors) to allow poor rough drafts to pass through regular channels on the assumption that so many people review the report that the author will be able to defer rewriting to a later time. Remember

that subsequent review will be less severe and time consuming if you carefully examine the original rough draft before submitting it to your immediate supervisor.

As an aid in evaluating your reports ask yourself these questions when reviewing your draft:

1. Are the purpose and scope of the report clearly stated?
2. Has the purpose been fulfilled?
3. Does the Introduction give the information needed to understand the results (or tell where to get it)? Are your assumptions clearly defined?
4. Did you say what you wanted to say? Do you mean what you said? Can what you said be misinterpreted?
5. Are the important results clear? Is the order of importance clear?
6. Are the limitations of the conclusions clearly stated?
7. Have you emphasized the most important results rather than the difficulty of the work?
8. Have you clearly separated facts from opinions?

In essence, these questions are the same ones that your supervisor and a review committee will be asking.

Technical Review Committee

Work to be published in a NASA Special Publication or Reference Publication must be reviewed by a committee. All other publications are reviewed by a committee or a single reviewer at the discretion of the division chief. (See the Technical Review Checklist.)

The technical review committee (TRC) usually consists of three or more persons selected by either the branch chief or the division chief. One person serves as chair, another as checker, and the others as advisors. The committee is usually given about 2 weeks in which to examine the report, and then a meeting is held between the committee and the author (or authors).

Objectives

The objectives of the TRC are to check the technical accuracy and clarity of a report and to ensure that it is worthy of publication and meets the standards required of NASA reports. The committee members share responsibility with the author for the technical soundness, logic of arrangement, and clarity of expression in the report. Each member of the committee should spend enough time on the report to effect a complete and judicious appraisal.

As a reviewer if you feel that your other duties may conflict with the review, by all means make this known to your supervisor. It is not fair to NASA or to the author of the report for you to neglect your responsibilities as a reviewer. Your duties in the normal course of

your work are certainly important, but they are no more so than your job as the reviewer of a report to be released to the general public.

As the author do not feel that you attend the review meeting to defend the report. Consider yourself not as the author of the report but as a member of the committee making a more critical examination of the report than the other members.

Occasionally the author and the committee members disagree on certain points. If disagreements are sufficiently serious, either the author or the committee members may submit memorandums backing their opinions to the division chief for a decision. This situation does not arise often, and both authors and committee members are urged to enter meetings with open minds ready to consider the report in an unbiased manner.

Reviewing Guidelines

All committee members should examine the figures and tables and each reference to the data in the text to determine that every statement is justified by the data presented. They should watch for conflicting statements and needless repetition. The member of the committee designated as checker should examine the raw data, the instructions and formulas used by the computers in converting the data, and the points on the curves to ascertain that the methods of computing and plotting are correct. In general, the committee's time should be spent in ensuring that the report is technically sound, leaving grammatical points to Editorial. But grammatical changes should be made when the technical clarity is in doubt.

The duty of the chair is to direct the review of the report so that the objectives of the committee are achieved harmoniously and efficiently. The chair should confine discussion to matters pertaining directly to the report. All suggestions should be clarified for the author, but modifying the report should be left to the author. When a report must be substantively altered, the chair may call a subsequent meeting.

Reviewers should become familiar with the requirements of each section of a report and watch for deviations as they review them. The title of a report should be brief but comprehensive. It should give readers an idea of the objective of the report stated in the Introduction. The title and the objective must, in turn, be related to the conclusions. Examine the conclusions carefully to be sure that the objective has been reached.

Another important point in reviewing a report is considering the reliability of the reference material. To do a conscientious job of report reviewing, one reviewer (e.g., the checker) should make sure that the material cited from a reference actually is in the reference. Many writers have the habit of recalling that a certain fact appeared in a particular reference, and if the reference is not handy to check the particular point, they will include it in the reference list without being certain that the reference is proper.

The reviewers should decide carefully whether the conclusions drawn by the author are logical and supported by the data. Conclusions from NASA reports are often quoted verbatim in other publications. Therefore their exact meaning and intent should be clear.

As mentioned before, the committee must evaluate the contribution of the report to a specific area of knowledge. This responsibility should be taken seriously by committee members and the author. They must be prepared to tell the division chief whether or not the report should be published.

Single Reviewer

The responsibilities of a single reviewer are the same as those of a TRC. The reviewer alone is responsible for evaluating the technical soundness and accuracy of the report and its value as a contribution. In assuming this significant burden the reviewer should feel as much responsibility as for his or her own technical reports.

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